Importation of Avocado Fruit (*Persea americana*) from Mexico

Supplemental Pest Risk Assessment

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I. Introduction

A. General

This supplemental pest risk assessment was prepared by the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture to examine plant pest risks associated with the importation of avocado fruits (*Persea americana*) grown in Mexico. However, this supplemental risk assessment is only one component of APHIS' overall analysis of risks associated with importations of Mexican avocado fruit. The primary components of APHIS' overall analysis are:

- **Risk Assessment Process:**
  - Initial risk assessments (*i.e.*, decision sheets for arthropod pests and pathogens of avocado in Mexico (APHIS, 1992; included as Attachments 1 and 2 of *Risk Management Analysis: A Systems Approach for Mexican Avocados* (APHIS, 1995)).
  - *Potential Economic Impacts of an Avocado Weevil Infestation in California* (APHIS, 1993).
  - *Economic Impact of the Establishment of Mexican Fruit Fly in the United States* (APHIS, 1993).
  - APHIS review of material submitted by Mexico (*e.g.*, *Proposed Work Plan for the Exportation of Hass Variety Avocado from Mexico to the United States* (Direccion General de Sanidad Vegetal (DGSV), 1994)).
  - APHIS review of other documents listed on pp. 2-3 of *Risk Management Analysis: A Systems Approach for Mexican Avocados*.
  - This supplemental risk assessment.

- **Risk Management Process:**
  - Establishment and subsequent meetings (at APHIS headquarters and on-site in Mexico) of the APHIS Oversight Group.
  - An analysis of a proposed risk mitigation program as reported in *Risk Management Analysis: A Systems Approach for Mexican Avocados* (APHIS, 1995).
  - APHIS review of over 300 comments received in response to the *Advance Notice of Proposed Rulemaking* (59 FR 59070-59071, Docket No. 94-116-1) regarding importation of Mexican avocado fruit (details of these 300 comments will be available for public comment should a draft regulation for importation of Mexican avocado fruit be published).

- **Risk Communication Process:**
  - Publication in the *Federal Register* (November 15, 1994) of the *Advance Notice of Proposed Rulemaking* (59 FR 59070-59071, Docket No. 94-116-1) regarding importation of Mexican avocado fruit.

- Consultation with outside experts (*e.g.*, State and Federal government officials, representatives of industry, academic researchers).
- Distribution of documents listed above in the risk assessment and risk management sections.
- Should APHIS decide to propose a program for importation of Mexican avocado fruit, a draft regulation will be published in the *Federal Register* for public scrutiny and comment.

APHIS' final decisions regarding importation of Mexican avocado fruit will rely on all of the risk analysis tools listed above. Although most of the documents listed above consider management options, it has not yet been determined that APHIS will pursue importations of Mexican avocado fruit. Nor has it been determined what measures would be used to manage plant pest risk should APHIS proceed with a proposed rule for importations of Mexican avocado fruit. A program has been proposed to mitigate plant pest risks (see *"Risk Management Analysis: A Systems Approach for Mexican Avocados"* (APHIS, 1995). In this supplemental risk assessment, we examine the risk associated with importations of Mexican avocado fruit with and without the proposed suite of mitigation measures. Should APHIS decide to propose a particular program to allow importation of Mexican avocado fruit, it would be published as a proposed rule in the *Federal Register* for comment by the public.

The primary components of this supplemental risk assessment are:

- A consideration of avocado pests found in Mexico and the U.S.
- A qualitative assessment of pest risk potential (quarantine pests)
- biological information on quarantine pests
- A scenario analysis considering the probability that infested fruit would be transported to suitable habitat (for quarantine pests)
- Quantitative estimates of THE likelihood that infested fruit would be transported to suitable habitat (quarantine pests)
- Brief recommendations regarding measures to manage plant pest risk

This supplemental risk assessment was "pathway-initiated" (*i.e.*, we initiated the assessment in response to the request by the Mexican government for permission to import a particular commodity). In this case, the importation of avocado fruit from Mexico into the U.S. is a potential pathway for introduction of plant pests. International plant protection organizations (*e.g.*, North American Plant Protection Organization (NAPPO), United Nations Food and Agriculture Organization (FAO)) provide guidance for conducting pest risk analyses. Pest risk assessment is defined as "Determination of whether a pest is a quarantine pest and evaluation of its introduction potential" (FAO, 1995) and quarantine pest is defined as "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (FAO, 1995; NAPPO/FAO, 1991)). Thus, pest risk assessments should consider both the likelihood and consequences of introduction of quarantine pests. Both issues are addressed in this supplemental pest risk assessment.

B. Historical perspective, Regulatory Authority, Current Importations

The impetus for restrictions on the importation of Mexican avocado fruit was to protect the health of U.S. avocado production. Quarantine 56 (7 CFR §319.56) provides a general regulatory authority for importation of fruits and vegetables. Avocado fruit from Mexico and Central America have been prohibited since 1914 because of a seed weevil, *Heilipus lauri*. In 1973 the specific avocado quarantine (by then several other pests had been identified) were incorporated into the general nursery stock (7 CFR §319.37) and fruit and vegetable quarantines (Quarantine 56, 7 CFR §319.56). In 1993, regulations allowed importation of Mexican avocado fruit into Alaska.

C. Proposed Action

This supplemental pest risk assessment covers importation of avocado fruit from Mexico. Over the past decade, the Mexican Government has made several requests for authorization to allow U.S. entry of Mexican avocado fruit. This issue has been discussed during several bilateral meetings between Mexico and the U.S. During that time, USDA has considered a plethora of approaches for mitigating plant pest risk associated with importations of Mexican avocado fruit. Many of the required features of a program that is likely to gain USDA approval have been determined and many are obvious mitigation measures that have proven efficacy. Although certain details of the program being proposed currently for importation of Mexican avocado fruit have already been determined, others still need to be refined before a final decision can be made regarding whether to allow importations. This supplemental pest risk assessment examines plant pest risk associated with the program being proposed currently. Details of the current proposed program are provided in *Risk Management Analysis: A Systems Approach for Mexican Avocados* (APHIS, 1995). In summary, the proposed program specifies the following:

- Only the Hass variety of avocado fruit would be imported.
- Hass avocado fruit would be imported from a single State in Mexico, Michoacan.
- Hass avocado fruit would be imported only from November through February.
- Hass avocado fruit would be imported only to 19 Northeastern States (Connecticut, Delaware, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin) and the District of Columbia (see Figure 1).
- Hass avocado fruit could be transported to these locations only under certain conditions designed to minimize plant pest risk.
- The United States would establish a program, and monitor compliance of the program to minimize the likelihood that plant pests would be introduced to the United States.
- The entire export program would be monitored by officials of the Mexican Government.
- The entire export program would be monitored by officials of the United States Government.

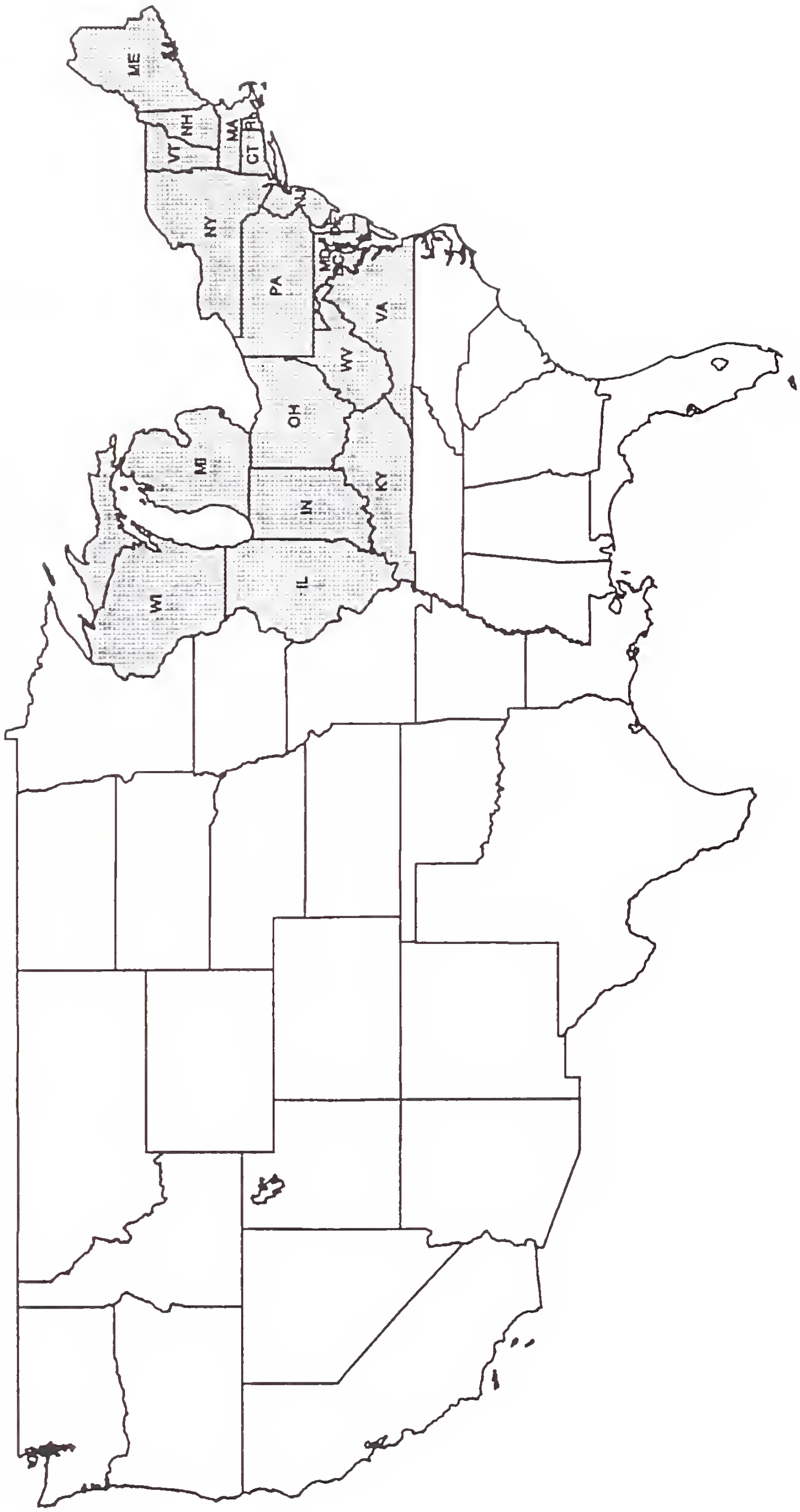


Figure 1: Area of the U.S. Proposed for Importation of Mexican Avocado Fruit.

Any proposed program would include specific requirements regarding:

- Regulatory controls to prevent movement of uncertified avocado fruit and plants into areas certified for production and processing.
- Field sanitation of Mexican avocado groves.
- Field trapping for specific avocado pests.
- Field surveys for specific avocado pests at the State, Municipality, and grove levels.
- Safeguarding of harvested avocado fruits to prevent post-harvest infestation.
- Certification of Municipalities and groves with respect to specific avocado pests.
- Certification of packing houses.
- Control of shipments.
- Inspection of imported fruits by U.S. officials in Mexico and again at the port of entry.

In this supplemental pest risk assessment, we consider two general scenarios: the proposed program for Michoacan Hass avocado fruits as described above and importations of Mexican avocado fruit without the elements of the proposed program listed above (*i.e.*, an assessment of "baseline risk").

D. Assessment of Weediness Potential of Avocado

The initial step after receiving a request for importation of a commodity is to analyze the weediness potential of the species to be imported. Table 1 shows how we assessed weediness potential and presents our findings for avocado. Because we found that the weediness potential of avocado was sufficiently low, we proceeded with this supplemental risk assessment.

E. Summary of Risk Assessment Methods

After determining that the commodity poses no significant risk as a weed, this supplemental pest risk assessment proceeds with five basic steps:

1. Pest List

The pest list includes limited pertinent information on the biology and distribution of each pest and selected references. We paid particular attention to pest—commodity association, current distribution, regulatory history, and interception records at U.S. ports.

2. Selection of Certain Quarantine Pests For Further Analysis

In addition to collecting basic information pests listed in Tables 2 and 3 (*i.e.*, see column labeled "Comments"), we collected more complete information on pests listed in Table 2 and 3 that do not occur in the U.S.. For pests that do not occur in the U.S., we

considered their potential for economic damage (*i.e.*, we determined which of the pests satisfied international guidelines as quarantine pests (FAO, 1995; NAPPO/FAO, 1991)). We conducted extended assessments on those quarantine pests that met certain criteria. Our criteria for whether to conduct an extended assessment on a particular pest are provided in Section II.B. The primary filter was whether it was reasonable to expect that the pest could remain with fruit during processing.

Table 1: Process for Assessing Weediness Potential of Plant Species

Species: Avocado, *Persea americana*

Answer Yes or No:

Is the species listed in:

NO — *Geographical Atlas of World Weeds* (Holm, 1979)

NO — *World's Worst Weeds* (Holm, 1977)

NO — *Report of the Technical Committee to Evaluate Noxious Weeds; Exotic Weeds for Federal Noxious Weed Act* (Gunn & Ritchie, 1982)

NO — *Economically Important Foreign Weeds* (Reed, 1977)

NO — Weed Science Society of America List (WSSA, 1989)

NO — Is there any literature reference indicating weediness (*e.g.*, *AGRICOLA*, *CAB*, *Biological Abstracts*, *AGRIS*; search "species name" combined with "weed").

IF:

1. All of the above answers are **no**,

   ✔ **THEN:** proceed with the supplemental pest risk assessment.

2. The answer to **one** of the above is yes,

   THEN: proceed with the supplemental pest risk assessment and incorporate findings regarding weediness into the Risk Elements described below.

3. The answer to **two or more** of the above is yes,

   THEN: Consult authority under the Federal Noxious Weed Act for listing plant species as a noxious weed.

3. Biological Information on Selected Quarantine Pests

Information on the biology of quarantine pests selected for further analysis are presented primarily in the initial pest risk assessments as shown in Attachments 1 and 2 of *Risk Management Analysis: A Systems Approach for Mexican Avocados* (APHIS, 1995).

4. Pest Risk Potential of Selected Quarantine Pests

We rated the risk potential of each pest with respect to five different risk elements. Criteria for estimating risks based on the risk elements were largely qualitative, but we assigned numerical values (0, 1, 2, or 3 points) for each element. The total of the five risk ratings provides a numerical estimate of pest risk potential for each pest.

5. Scenario Analysis for Selected Quarantine Pests

We used Scenario Analysis to conceptualize the events that would have to occur before pests could be introduced with commercial shipments of avocado fruit.

6. Quantitative Risk Assessment on Selected Quarantine Pests

We used quantitative risk assessment techniques to analyze pests for which we obtained a risk rating of ten or more (*i.e.*, the pest presents moderate or high plant pest risk). We analyzed either individual pests (*e.g.*, the avocado seed moth, *Stenoma catenifer*) or groups of pests with similar biologies (*e.g.*, four species of fruit flies in the genus *Anastrepha*).

II. Pests Associated with Avocado in Mexico

A. Pest List

Our pest lists for Mexican avocado are given in Tables 2 (pathogens) and 3 (arthropods). The lists were generated after review of the following references and resources:

- Literature reviews using the AGRICOLA and CAB databases and the University of California computer information system (MELVYL).
- Previous decision sheets covering the importation of avocados from Mexico, Jamaica and Central America.
- The United States catalogue of intercepted pests and interception records.
- C.M.I. Distribution Maps and Descriptions of Plant Pathogenic Fungi and Bacteria, and Arthropods.
- Texts and indices of plant diseases and pathogens as listed in the bibliography section at the end of this assessment.
- APHIS' files on pests not known to occur in the U.S. (*e.g.*, PNKTO's—Pests Not Known To Occur and INKTO's—Insects Not Known To Occur).

All pests listed in Tables 2 and 3 occur in Mexico. The list includes both nonindigenous (*i.e.*, does not occur in the U.S.) and domestic (*i.e.*, occurs in the U.S.) pests associated with avocado in Mexico. For each pest in Tables 2 and 3:

- We state explicitly that the pest occurs in Mexico.
- We indicate whether the pest occurs in the U.S.
- We provide limited pertinent comments regarding the biology and regulatory history (*e.g.*, interception records), all pests intercepted at U.S. ports on avocado fruit from Mexico are included on the pest list.
- We provide selected references on the biology/distribution of the pest.

While preparing these lists, we assumed that all Quarantine 56 conditions would be in effect: only fruit would be shipped and no stems or leaves or any other kind of plant material would accompany the fruit; we assumed that all traces of stems and other plant material would be removed before packing. This assumption affects risk management.

Table 2: Pest List — Mexican Avocado: Pathogens.

Scientific Name [1] and Common Name	Distribution [2]	Comment [3]	References
Fungi			
Armillaria mellea (Vahl:Fr.) P. Kumm. Armillaria root rot	MX CA FL OT	a, c	Ploetz, *et al.*, 1994; CMI, 1980a
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. in Penz. Teleomorph: *Glomerella cingulata* (Stone.) Spauld. & H. Schrenk Anthracnose	MX CA FL HI TX OT	c, f	Ploetz, *et al.*, 1994
Diaporthe rudis (Fr:Fr) Nitschke Synonym: *Diaporthe medusaea* Nitschke Melanose	MX CA FL TX OT	c, f	Kranz, *et al.*, 1977
Ganoderma lucidum (Curtis:Fr) P. Karst. Wood rot	MX CA FL TX OT	a, f	Morales-Garcia, 1989; Farr, *et al.*, 1989; CMI, 1975
Lasiodiplodia theobromae (Pat.) Griffon & Maubl. Stem-end rot	MX CA FL OT	c, f	Alfieri, *et al.*, 1984; CMI, 1976
Mycosphaerella perseae L.E. Miles Leaf spot	MX FL	a, f	Farr, *et al.*, 1989; Alfieri, *et al.*, 1984
Phyllachora gratissima Rehm. Tar spot	MX	a, x	Watson, 1971
Phymatotrichopsis omnivora (Duggar) Hennebert Texas foot rot	MX CA TX	a, c, f	Morales-Garcia, 1989

Table 2: Pest List — Mexican Avocado: Pathogens.

Scientific Name [1] and Common Name	Distribution [2]	Comment [3]	References
Phytophthora cinnamomi Rands Phytophthora root rot	MX CA FL TX OT	a, f	Ploetz, *et al.*, 1994; CMI, 1991
Phytophthora citricola Sawada Black fruit rot	MX CA OT	c, f	Fucikovsky & Luna, 1987; Ploetz, *et al.*, 1994; CMI, 1979
Phytophthora nicotianae Breda de Haan var. *parasitica* (Dastur) G.M. Waterhouse Collar rot	MX CA FL OT	c, f	Alfieri, *et al.*, 1984; Farr, *et al.*, 1989; CMI, 1964
Pseudocercospora purpurea (Cooke) Deighton Synonym: *Cercospora purpurea* Cooke Cercospora spot, Blotch	MX CA FL	c, f	Fucikovsky & Luna, 1987; Ploetz, *et al.*, 1994
Pythium ultimum Trow Root rot	MX CA FL HI OT	a, c, f	French, 1989; CMI, 1981b
Rhizoctonia solani Kühn Root rot	MX CA FL TX OT	a, c, f	Alfieri, *et al.*, 1984; Farr, et al., 1989; French, 1989; CMI, 1974
Rosellinia bunodes (Berk. & Br.) Sacc. Black (Rosellinia) root rot	MX	a	Ploetz, *et al.*, 1994; Watson, 1971; CMI, 1985
Rosellinia necatrix Prill. Anamorph: *Dematophora necatrix* R. Hartig White root rot	MX CA OT	a, f	Ploetz, *et al.*, 1994; CMI, 1987

Table 2: Pest List — Mexican Avocado: Pathogens.

Scientific Name [1] and Common Name	Distribution [2]	Comment [3]	References
Rosellinia pepo Pat. Black root rot	MX	a	Ploetz, *et al.*, 1994; CMI, 1968
Sclerotium rolfsii Sacc. Anamorph: *Corticium rolfsii* Curzi Seedling blight	MX CA FL HI TX OT	c, f	Alfieri, *et al.*, 1984; CMI, 1981a
Sphaceloma perseae Jenkins Scab	MX CA FL TX	c, f, x	Ploetz, *et al.*, 1994; CMI, 1986a
Verticillium albo-atrum Reinke & Bert. Verticillium wilt	MX CA FL TX OT	a, c, f	Ploetz, *et al.*, 1994; Morales-Garcia, 1989; CMI, 1986b
Bacteria			
Agrobacterium tumefaciens (Smith & Town.) Conn Crown gall	MX CA FL TX OT	a, c, f	Bradbury, 1986; CMI, 1980b
Erwinia carotovora subsp. *carotovora* (Jones) Bergey *et al.* Soft rot	MX CA FL HI TX OT	c, f	Bradbury, 1986
Erwinia herbicola (Löhnis) Dye	MX CA FL HI TX OT	f	Bradbury, 1986; Fucikovsky & Luna, 1987
Pseudomonas syringae pv. *syringae* van Hall Fruit spot, Blossom blight, Blast	MX CA FL TX OT	c, f	Bradbury, 1986; CMI, 1988
Nematodes			
Radopholus similis (Cobb) Thorne	MX CA FL TX OT	a, f	Anonymous, 1984; Ploetz, *et al.*, 1994; Anonymous, 1992

Table 2: Pest List — Mexican Avocado: Pathogens.

Scientific Name[1] and Common Name	Distribution[2]	Comment[3]	References
Virus, viroid and viruslike agents			
Avocado sunblotch viroid	MX CA FL	f	Fucikovsky & Luna, 1987; Ploetz, *et al.*, 1994

[1] Scientific names of fungi and bacteria as listed in Ploetz, *et al.*, 1994; Bradbury,1986; and Farr, *et al.*,1989.

[2] Distribution legend: MX = Mexico; CA = California; FL = Florida; HI = Hawaii; TX = Texas; OT = Other, occurs in states other than CA, FL, HI, TX.

[3] Comments:

a = Pest mainly associated with plant part other than commodity

c = Listed in U.S. Department of Agriculture (USDA) catalogue of pest interceptions as non-actionable

f = Pest occurs in the U.S. and is not currently subject to official restrictions and regulations (*i.e.*, not listed as actionable or non-actionable, and no official control program)

x = Multiple interception records exist

Table 3: Pest List — Mexican Avocado: Arthropods

Genus species Author (Order: Family)	Distribution[1]	Comments[2]	References
Acutaspis albopicta (Cockerell) (Homoptera: Diaspididae)	MX, US	a, g, j	Nakahara, 1982
Acutaspis perseae (Comstock) (Homoptera: Diaspididae)	MX, US	a, j	Ebeling, 1959
Aetalion quadratum Fowler (Homoptera: Aetalionidae)	MX	a, g	Ebeling, 1959
Aleurocanthus woglumi Ashby (Homoptera: Aleyrodidae)	MX, US	a, g	Ballou, 1922; PNKTO No.15
Aleurodicus dugesii (Cockerell) (Homoptera: Aleyrodidae)	MX	a, g	Ebeling, 1959
Amorbia emigratella Busck (Lepidoptera: Tortricidae)	MX, US	a, c	Ebeling, 1959
Anastrepha fraterculus (Wiedemann) (Diptera: Tephritidae)	MX	z	Norrbom & Kim, 1988
Anastrepha ludens (Loew) (Diptera: Tephritidae)	MX, US	z, g, w	Norrbom & Kim, 1988; 7 CFR 301.64
Anastrepha serpentina (Wiedemann) (Diptera: Tephritidae)	MX	z, g	Norrbom & Kim, 1988
Anastrepha striata (Diptera: Tephritidae)	MX	z, g	Ballou, 1936
Apate monacha F. (Coleoptera: Bostrichidae)	MX	a, g	Pierce, 1917
Aphis gossypii Glover (Homoptera: Aphididae)	MX, US	a, c	Ebeling, 1959
Brochymena quadripustulata F.(Heteroptera: Pentatomidae)	MX, US	a, c	Alvarez *et al.*, 1967; Henry & Froeschner, 1988
Burtinus notatipennis Stal (Heteroptera: Coreidae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
Capaneus humerosus Distant (Heteroptera: Coreidae)	MX	a	Ebeling, 1959

Table 3: Pest List — Mexican Avocado: Arthropods

Caulophilus latinasus Say (Coleoptera: Curculionidae)	MX, US	a, c	McKenzie, 1935
Ceroplastes cirripediformis Comstock (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
Ceroplastes cistudiformis Townsend & Cockerell (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
Ceroplastes floridensis Comstock (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
Ceratitis capitata (Wiedemann) (Diptera: Tephritidae)	MX, US	g, l, w, z	Metcalf & Metcalf, 1993; White & Elson-Harris, 1992 7 CFR 301.78; 7 CFR 318.13;
Chrysomphalus agavis (Townsend & Cockerell) (Homoptera: Diaspididae)	MX, US	a, j	Ebeling, 1959
Chrysomphalus aonidum (L) (Homoptera: Diaspididae)	MX, US	a, c, j	Metcalf & Metcalf, 1993
Coccus hesperidum (L) (Homoptera: Coccidae)	MX, US	a, c	Ebeling, 1959
Conotrachelus aguacatae Barber (Coleoptera: Curculionidae)	MX	z, g	Arellano, 1975
Contrachelus perseae Barber (Coleoptera: Curculionidae)	MX	z, g	Ebeling, 1959
Copturus aguacatae (Coleoptera: Curculionidae)	MX	z, g	MacGregor & Gutierrez, 1983; PPQ interception records
Copturus constrictus Champion (Coleoptera: Curculionidae)	MX	a	Sleeper, 1978
Corthylus nudus Schedl (Coleoptera: Scolytidae)	MX	a	MacGregor & Gutierrez, 1983
Deloyala guttata (Olivier) (Coleoptera: Chrysomelidae)	MX	a, c	Ebeling, 1959
Diaprepes abbreviatus (L) (Coleoptera: Curculionidae)	MX, US	a, g	Bennett, 1985

Table 3: Pest List — Mexican Avocado: Arthropods

Dysdercus obliquus (Herrich-Schaeffer) (Heteroptera: Pyrrhocoridae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
Farinococcus olivaceus (Cockerell) (Homoptera:Pseudococcidae)	MX	a	Ebeling, 1959
Frankliniella cephalica (Crawford) (Thysanoptera: Thripidae)	MX, US	a, c	Ebeling, 1959
Hansenia pulverulenta (Guerin-Meneville) (Homoptera:Flatidae)	MX	a	MacGregor & Gutierrez, 1983
Heilipus albopictus Champion (Coleoptera: Curculionidae)	MX	a	MacGregor & Gutierrez, 1983
Heilipus lauri Bohemann (Coleoptera: Curculionidae)	MX	z, g	Ebeling, 1959
Heliothrips haemorrhoidalis (Bouche) (Thysanoptera:Thripidae)	MX, US	a, c	Ebeling, 1959
Hemiberlesia lataniae (Signoret) (Homoptera: Diaspididae)	MX, US	a, c, j	Nakahara, 1982
Hemiberlesia rapax (Comstock) (Homoptera: Diaspididae)	MX, US	a, c, j	Nakahara, 1982
Icerya montserratensis Riley & Howard (Homoptera: Margarodidae)	MX	a, g	Ebeling, 1959
Icerya purchasi Maskell (Homoptera: Margarodidae)	MX, US	a, c	Ebeling, 1959
Idona spp. (Homoptera: Cicadellidae)	MX, US	a	Ebeling, 1959
Largus cinctus Herrich-Schaeffer (Heteroptera: Largidae)	MX, US	a, c	Ebeling, 1959; Henry & Froeschner, 1988
Leptoglossus phyllopus (L) Heteroptera: Coreidae)	MX US	a, c	Ebeling, 1959
Liothrips perseae (Watson) Thysanoptera: Phlaeothripidae	MX	a	MacGregor & Gutierrez, 1983; Nakahara, 1995
Melanaspis aliena (Newstead) (Homoptera: Diaspididae)	MX	a, j	Nakahara, 1982

Table 3: Pest List — Mexican Avocado: Arthropods

Melipona testacea cupira Smith (Hymenoptera: Meliponidae)	MX	a	Ebeling, 1959
Metcalfiella monogramma (Germar) (Homoptera: Membracidae)	MX	a, g	Ebeling, 1959
Mycetaspis personata (Comstock) (Homoptera: Diaspididae	MX, US	a, c, j	Nakahara, 1982
Nipaecoccus nipae (Maskell) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
Oligonychus yothersi (McGregor) (Acarina: Tetranychidae)	MX, US	a	MacGregor & Gutierrez, 1983; McMurtry, 1985
Oligonychus platani (McGregor) (Acarina: Tetranychidae)	MX, US	a, c	MacGregor & Gutierrez, 1983; McMurtry, 1985
Oligonychus punicae (Hirst) (Acarina: Tetranychidae)	MX, US	a, c	McMurtry, 1985
Paraleurodes sp. near *goyabae* (Goeldi) (Homoptera: Aleyrodidae)	MX	a	Ebeling, 1959
Planococcus citri (Risso) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
Pseudacysta perseae (Heidemann) (Heteroptera: Tingidae)	MX, US	a, c	MacGregor & Gutierrez, 1983; Henry & Froeschner, 1988
Pseudococcus longispinus (Targioni-Tozzetti) (Homoptera: Pseudococcidae)	MX, US	a, c	Ebeling, 1959
Pulvinaria simulans Cockerell (Homoptera: Coccidae)	MX	a	Ebeling, 1959
Pyrrhopyge chalybea Scudder (Lepidoptera: Hesperiidae	MX	a, g	Diaz, 1976
Saissetia coffeae (Walker) (Homoptera: Coccidae)	MX, US	a, c	Metcalf & Metcalf, 1993
Saissetia hemisphaerica (Targioni) (Homoptera: Coccidae)	MX, US	a	Ebeling, 1959
Scaphytopius sp. (Homoptera: Cicadellidae)	MX	a, g	Ebeling, 1959

Table 3: Pest List — Mexican Avocado: Arthropods

Stenoma catenifer Walsingham (Lepidoptera: Oecophoridae)	MX	z, g	Ebeling, 1959
Trialeurodes similis Russell (Homoptera: Aleyrodidae)	MX	a, c	Ebeling, 1959
Trioza anceps Tuthill (Homoptera: Psyllidae)	MX	a, g	MacGregor & Gutierrez, 1983

[1] Distribution legend: MX = Mexico; US = United States.

[2] Comments:

a = Pest mainly associated with plant part other than commodity.

c = Listed in U.S. Department of Agriculture (USDA) catalogue of pest interceptions as non-actionable.

g = Listed in the USDA catalogue of intercepted pests as actionable.

j = Armored scale insect: no quarantine action taken on fruit for consumption because "...armored scales in general have a low probability of establishment from infested shipments of commercial fruit" (ARS, 1985).

l = Pest reported to occur in export country but not known to occur in area of production and processing.

w = Program pest, occurs in the U.S. but not widely distributed and being officially controlled.

z = Pest is known to commonly attack or infect fruit and it would be reasonable to expect the pest may remain with the fruit during processing and shipping.

B. Quarantine Pests Selected for Further Analysis

For consistency with international guidelines, we performed extended assessments only on pests that qualified as quarantine pests (see definition in section I.A.). Thus, pests selected for further analysis satisfied the following criteria:

1. Pest is of potential economic importance to avocado producing areas of the U.S. (according to international guidelines).
2. Pest does not occur in the U.S., or the pest has limited distribution in the U.S. and is being controlled officially (according to international guidelines).
3. Pest is known to be a pest of the commodity and not just the plant species.
4. It would be reasonable to expect that the pest may remain with the fruit during processing.

To be considered in more detail pests must reasonably be expected to remain on the fruit during processing in order to have an opportunity to be shipped along with the fruit. This assumption eliminated many serious avocado pests from further consideration. For example, we did not consider further arthropods that feed strictly on leaves; although these are serious pests, they do not normally attack the fruit and phytosanitary conditions required to satisfy existing regulations (*e.g.*, Quarantine 56) are sufficient to ensure that these pests do not accompany shipments of fruit. Although Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), is on the pest list (Table 3) and meets all four of the conditions listed above, we did not analyze Medfly further because it is not known to occur in the Mexican State of Michoacan.

When determining whether each of the pathogens on the pest list warranted further evaluation, several factors were examined. First, the biology of the pathogen was reviewed to determine whether or not the pest is associated with the plant part to be shipped (*i.e.*, the fruit). We evaluated several factors in deciding whether each pathogen on the list could legitimately be considered a quarantine pest under current proposed international standards. Specifically, we asked if the pathogens were or were not present in the United States. For those pathogens present in the United States, we looked at their distribution and whether any official control programs or regulations related to them were in place. Only those pathogens that either are not present in the United States or are present but are not widely distributed and officially regulated, fit the international standard for quarantine pests and were chosen for further evaluation. Although a number of serious pathogens are included in the pest list (*e.g.*, *Phytophthora cinnamomi*), none of the pathogens listed satisfied the criteria for quarantine pests. Consequently, no pathogens were chosen for further evaluation.

Of the pathogens listed in Table 2, only three do not occur in the U.S. (*i.e.*, only those three are candidates as quarantine pests). However, the three potential quarantine pathogens cause leaf spots and root rots and therefore are associated with plant parts other than fruit. Thirty (30) arthropods were candidates as quarantine pests because they do not occur in the U.S. Although some of the pests listed in Tables 2 and 3 are serious pests of avocado, and they satisfy international guidelines as quarantine pests, we did not analyze them further by conducting an extended assessment. There were a variety of reasons for not analyzing particular pests further (not all reasons apply to all pests), the most common reasons were:

- Pest occurs in the U.S. and there is no official Federal program for controlling the pest or regulating its interstate movement, or
- Pest is associated mainly with plant parts other than the plant part to be imported, or
- We did not consider it reasonable to expect these pests would remain with the fruit during processing, or
- Pest is listed as non-actionable at U.S. ports of entry.

For example, there are insects in Mexico that attack avocado but feed on plant parts other than fruit (*e.g.*, *Pyrrhopyge chalybea*, leaf feeder). However, we considered the probability that any life stage of these insects would remain with mature fruit during processing to be quite low. Our list of pests selected for further analysis includes nine arthropods:

- *Anastrepha fraterculus* - fruit fly
- *Anastrepha ludens* - fruit fly
- *Anastrepha serpentina* - fruit fly
- *Anastrepha striata* - fruit fly
- *Conotrachelus aguacatae* - seed weevil
- *Conotrachelus perseae* - seed weevil
- *Heilipus lauri* - seed weevil
- *Copturus aguacatae* - stem weevil
- *Stenoma catenifer* - seed moth

We categorized these nine pests for the purposes of our extended assessment as follows:

- **fruit flies:** *Anastrepha fraterculus, A. ludens, A. serpentina, A. striata*
- **seed weevils:** *Conotrachelus aguacatae, C. perseae, Heilipus lauri*
- **stem weevil:** *Copturus aguacatae*
- **seed moth:** *Stenoma catenifer*

III. Extended Assessment, Selected Quarantine Pests

A. Estimates of Pest Risk Potential

We estimated a pest risk potential (PRP) for each of the pest categories listed in the previous section as candidates for further analysis. For each risk element (see below) each pest is assigned a risk value of **high** (3 points), **medium** (2 points), **low** (1 point), or **not/none** (0 points) as indicated.

The lowest possible PRP is 3; pests with RP values of 3-6 are not considered to represent any significant risk, low risk pests have PRP values of 7-9, medium risk pests have PRP values of 10-12, and high risk pests have PRP values of 13-15. The PRP is considered to be a biological indicator of the potential destructiveness of the pest.

Risk Element #1: Climate—Host Interaction

When a pest is introduced to a new area, if host plants are available and climatic conditions are similar to its native area, it can be expected to behave as it does in its native area. The evaluation will consider ecological zonation, interaction between the geographic distribution of the pest and geographic distribution of the host. For this element, risk values are based on the availability of both host material and suitable climate conditions. To rate this risk element, we use the U.S. "Plant Hardiness Zones" as described by the U.S. Department of Agriculture (see Figure 2) (Cathey, 1990). Risk values were assigned according to the following. Due to the availability of both suitable host plants and suitable climate, the pest has potential to establish a breeding colony:

High (3):	In four or more plant hardiness zones.
Medium (2):	In two or three plant hardiness zones.
Low (1):	In only a single plant hardiness zone.
None (0):	In none of the plant hardiness zones.

Risk Element #2: Host range

The risk posed by a plant pest depends on both its ability to establish a viable reproductive population and its potential for causing plant damage. We assumed risk is correlated positively with host range. For pathogens, risk is more complex and depends on host range, aggressiveness, virulence and pathogenicity. For both arthropods and pathogens, we rated risk primarily as a function of host range as follows:

High (3):	Pest attacks multiple species within multiple plant families.
Medium (2):	Pest attacks multiple species within a single plant family.
Low (1):	Pest attacks only a single species or multiple species within a single genus.

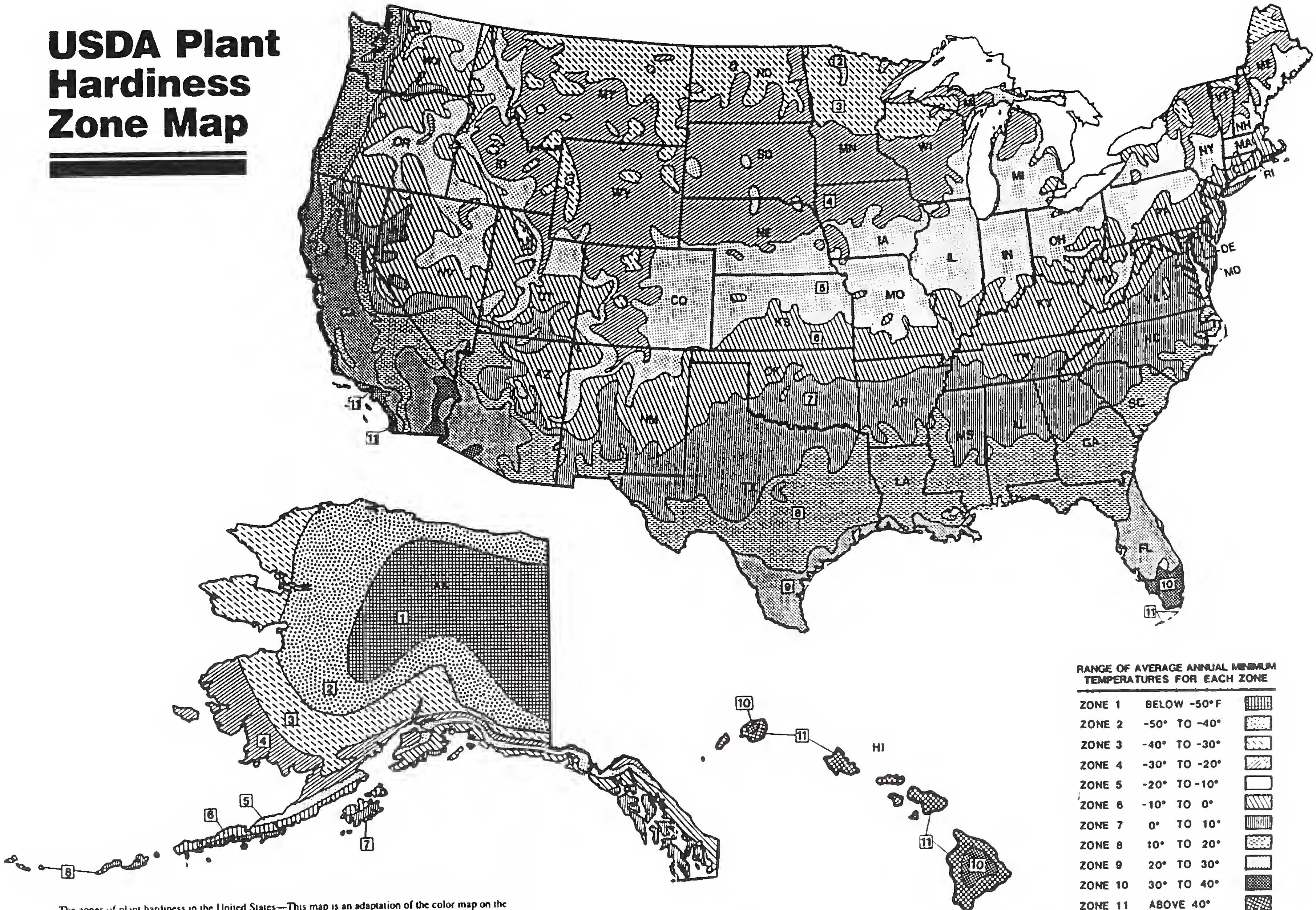
Risk Element #3: Dispersal Potential

A pest may disperse after establishment in a new area. Consider the following:

- reproductive patterns in the pest (*e.g.*, voltinism, reproductive output)
- innate dispersal capability of the pest
- whether natural factors (*e.g.*, wind, water, presence of vectors) facilitate dispersal

High (3):	Pest has high reproductive potential (*e.g.*, multiple generations or cohorts per year, many offspring per reproductive event, high innate capacity of a population for increase (*i.e.*, the species is "r-selected"), *AND* individuals are highly mobile (*i.e.*, capable of moving long distances — at least 20 km — either under their own power, or by being moved by natural forces such as wind, water or vectors).
Medium (2):	Pest has either high reproductive potential ***OR*** the species is motile.
Low (1):	Neither high reproductive potential nor highly mobile.

USDA Plant Hardiness Zone Map



The zones of plant hardiness in the United States—This map is an adaptation of the color map on the reverse side. It lacks many fine details of the color map but may be useful for small-scale reproduction in books, magazines, and nursery catalogs.

Figure 2

Risk Element #4: Economic Impact

Introduced pests are capable of causing a variety of economic impacts. We divide these impacts into three categories:

1. Lower yield of the host crop (*e.g.*, by causing plant mortality, or by acting as a disease vector)
2. Lower value of the commodity (*e.g.*, by increasing costs of production, lowering market price, or a combination)
3. Loss of markets (foreign or domestic).

High (3):	Pest causes all three types of impacts.
Medium (2):	Pest causes any two of the above impacts.
Low (1):	Pest causes any one of the above impacts.
None (0):	Pest does not cause any of the above impacts.

Risk Element #5: Environmental Impact

Consider the following four elements:

1. Establishment of the pest is expected to cause significant, direct environmental impacts (*e.g.*, ecological disruptions, reduced biodiversity).
2. Pest is expected to have direct impacts on species listed by Federal or State agencies as endangered, threatened, or candidate. An example of a direct impact would be feeding on a listed plant. If feeding trials with the pest have not been conducted on the listed organism (no direct negative data), a pest will be expected to feed on the plant if it feeds on other species within the genus or other genera within the family.
3. Pest is expected to have indirect impacts on species listed by Federal or State agencies as endangered, threatened, or candidate species (*e.g.*, by disrupting sensitive, critical habitat).
4. Establishment of the pest would stimulate control programs consisting of toxic chemical pesticides, or release of nonindigenous biological control agents.

High (3):	Two or more of the above.
Medium (2):	One of the above.
Low (1):	None of the above (it is assumed that establishment of a nonindigenous pest will have at least some environmental impact).

This information is displayed in tabular form with scores for each of the risk elements for each pest (Table 4). The risk potential of each pest is estimated by adding together the risk values (one for each risk element).

Table 4. Risk estimates (see section III of text for descriptions of risk elements and assignment of risk values)						
Pest	Climate/ Host Interaction	Host range	Dispersal Potential	Economic Impact	Environ-mental Impact	TOTAL
Fruit flies	2	3	3	3	2	13
Seed weevils	2	1	2	3	2	10
Stem weevils	2	1	2	3	2	10
Seed moth	2	2	2	3	2	11

B. Scenario Analysis

Plant pest risk is composed to two general elements, the consequences of introduction of a particular pest and the probability that the pest will be introduced. Our assessment of the consequences of introduction are presented in the previous section with the results shown in Table 4. The next step was to estimate the probability that particular quarantine pests would be introduced. After estimating pest risk potentials, we proceeded with the extended assessments on pests that we rated to be of medium or high risk (*i.e.*, PRP's of 10 or greater). All four pests/pest categories were rated as 10 or greater providing further confirmation that they satisfied international standards as quarantine pests.

We estimated the probability that particular pests would be introduced as a result of importation of Mexican avocado fruit in two steps. First, we conceptualized the events that would have to occur before pest outbreaks could occur using the method of **Scenario Analysis**. We then used the results of our scenario analysis to run a series of Monte Carlo simulations to estimate the frequency of pest outbreaks (see next section). Figure 3 shows the scenario we considered. Our chosen endpoint for the simulations was the frequency of pest outbreaks.

We considered two scenarios (*i.e.*, program alternatives):

Program alternative A: Importation of Mexican avocado fruit with no specific measures to mitigate plant pest risks:

- All avocado cultivars are enterable (*i.e.*, importations of avocado fruit not limited to the Hass cultivar).
- Unregulated entry into U.S. (*e.g.*, no regulatory controls to prevent movement of uncertified fruit and plants into areas certified for production and processing).

- Routine certification for U.S. shipments
- No special field surveys to meet U.S. standards
- No special trapping and field treatments to meet U.S. standards
- Normal field sanitation
- No post-harvest safeguards (*e.g.*, tarping of harvested fruits in transit to packing house)
- No U.S. required DGSV inspection of municipalities
- No U.S. required DGSV inspection/certification of groves
- No U.S. inspection/certification of packing houses
- No U.S. fruit cutting at packing house
- No requirement for refrigerated shipping containers
- Importation of fruit allowed to all States
- Importation of fruit allowed during all months

However, as with all shipments of imported fruits, there would be a port of entry inspection.

Program alternative B: Systems Approach

Importations of only Hass avocado fruit and only under a Systems Approach for mitigating plant pest risk as specified in Section I.C. of this supplemental risk assessment and *Risk Management Analysis: A Systems Approach for Mexican Avocados* (APHIS, 1995).

C. Monte Carlo Simulations

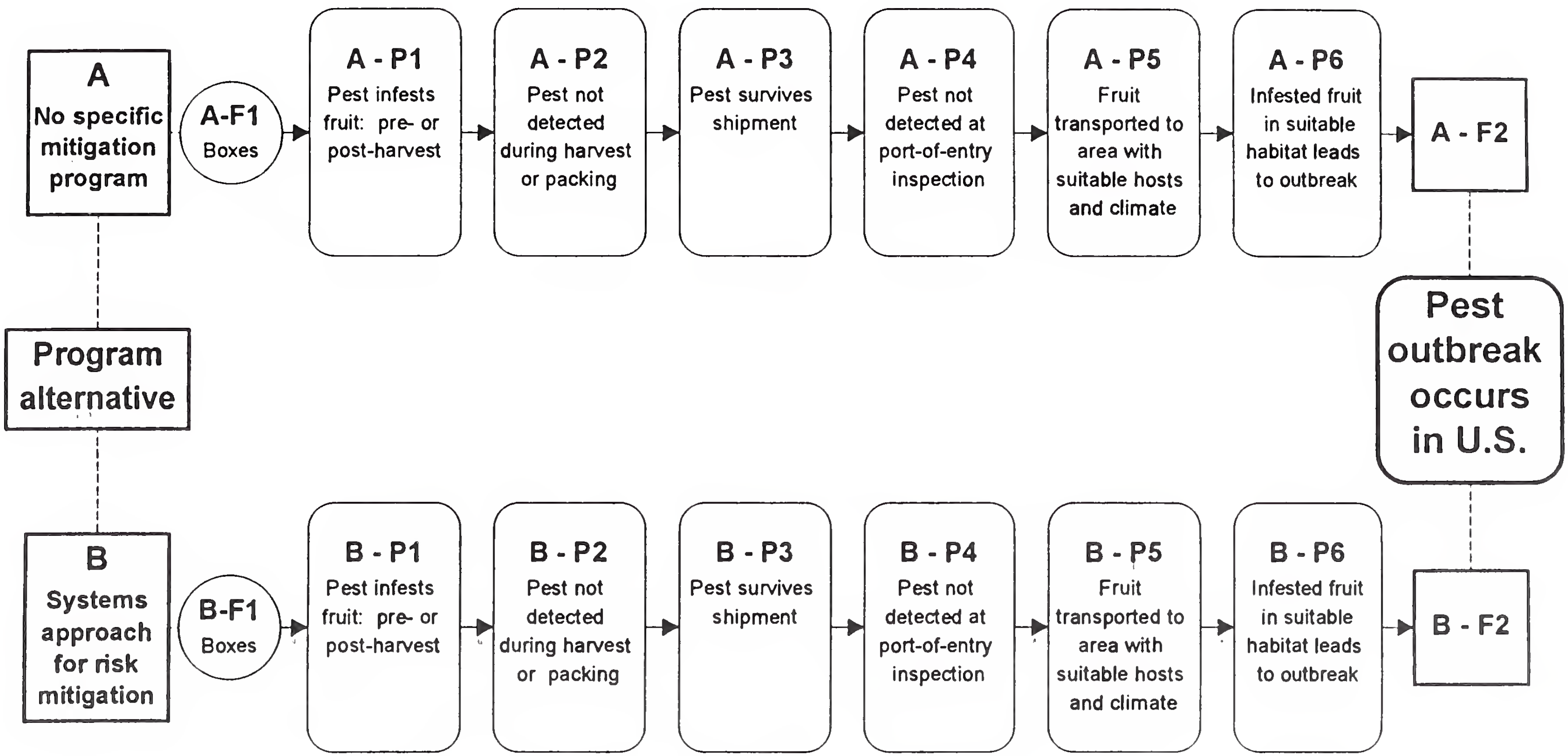
a. General

We use the term "Monte Carlo simulation" to refer to the process used to calculate our estimated probabilities of pest outbreaks. The process consisted of the following three steps (details of each of these three steps are provided below in Sections III.C.b.1-3):

1. Develop a mathematical model to estimate the probabilities of pest outbreaks.
2. Estimate probabilities for each component event in the model.
3. Calculate estimated probabilities of pest outbreaks using Monte Carlo sampling techniques.

Throughout the scenario analysis and Monte Carlo simulations our unit of measure was one shipping box of avocado fruit. In many instances these are the same boxes used on retail shelves. Shipping boxes of avocado fruit generally contain 12-20 fruit (depending on fruit size). We used a standard of 16 fruit per box.

Figure 3. Scenario Analysis: Importation of Mexican Avocado Fruit



Legend: 'F' represents a frequency, 'P' represents a probability (*e.g.*, 'A-P1' = estimated probability that event '1' will occur under program alternative A)

b. Methods

1. Develop mathematical model.

Outbreak probabilities were calculated based on the model shown in Figure 3. Before a pest outbreak can occur, all of the independent events shown in Figure 3 must occur. We used a simple multiplicative model to calculate estimated frequency of pest outbreaks. Use of this model was appropriate and justified by the fact that:

- each of the events in Figure 3 are independent, and
- all of the events must occur before a pest outbreak can occur.

To calculate the estimated frequency of pest outbreaks, we multiplied the number of boxes of avocado fruit imported per year (A-F_1 or B-F_1) by the probability of the first event (A-P_1 or B-P_1, respectively). The resulting product was multiplied by A-P_2 or B-P_2 (respectively) and so on through A-P_6 and B-P_6. Because the probabilities are given on a per box basis, the frequency of pest outbreaks (A-F_2 and B-F_2) is on a per year basis.

2. Estimated probabilities for each event in the model.

Because the actual probabilities of the independent events shown in Figure 3 are not known, we estimated them. Although the probabilities were estimated, pertinent data were available for each independent event. However, it must be emphasized that these are only estimates with various levels of uncertainty. All estimated probabilities are on a per box basis. Our estimates were based to a large extent on expert judgment. A core team of four entomologists estimated probabilities. Additionally, numerous technical specialists (*e.g.*, scientists specializing on particular taxonomic groups, port inspectors, specialists in international trade, *etc.*) were consulted throughout the process regarding various details. Estimates were made at each node based on the following:

- Pest interception records on Mexican avocado fruits
- General biology of pest group
- Judgement based on laboratory experience
- Judgement based on field experience
- Judgement based on inspection experience
- Pest association with export quality fruit

Values at a particular node for the various pests were considered relative to each other. Our estimated probabilities are shown in Tables 5-8. Following is a brief discussion of factors that were considered during estimation and our rationale for choosing certain values:

F1: Boxes (i.e., number of boxes imported per year)

We based our estimates on published agricultural statistics for avocado fruit and on the the quantity of avocado fruit currently (Fiscal Year 1994) being shipped by truck through the U.S. from Mexico to Canada. During 1994, 14,251,77 kg of avocado fruit transited the U.S. under the approved program. This corresponds to approximately 2,780,000

boxes of avocado fruit. From this figure we estimated that the market in the northeastern U.S. during the months of November through February would be about half this amount. We used a uniform distribution with a minimum estimate of one million per year and a maximum estimate of two million per year under program alternative B. For program alternative A (*i.e.*, all States, all months), we estimated that the maximum amount of fruit imported could increase by an order of magnitude (*i.e.*, a factor of 10). We estimated the minimum under program A to be the same as the maximum under program B. This provided minimum and maximum estimates for program B of 2 million and 20 million boxes of avocado fruit per year.

P1: Pest Infests fruit: pre- or post-harvest

Mexico currently exports avocado fruit to a number of countries and maintains a variety of mitigation methods to minimize the probability of pest infestations in export groves. Trapping and distribution data exist for all of the pests included in the extended assessment. Based on these data and under program alternative A (*i.e.*, no specific U.S. program), we estimated the probability that an export grove would be infested to be highest for the seed weevils and equally low for the others pests. With a specific program designed and monitored program for the pests in question (*i.e.*, program alternative B) we expected the probability of pest infestation to decrease by at least one order of magnitude and that the least likely infestation would be fruit flies. For some of these pests (*e.g.*, *Heilipus lauri*, *Stenoma catenifer*) we could find no evidence that they had ever been trapped in the State of Michoacan. However, negative trapping data exist. Thus, we estimated conservatively (*i.e.*, admittedly high) for probability of infestation.

P2: Pest not detected during harvest or packing

APHIS experience with inspecting avocado fruit suggested that compared to the avocado weevils, it would be easier to detect the fruit flies and seed moths; there would be a lower probability of not detecting the fruit flies and seed moth. The probability of not detecting the weevils was estimated to be twice that for the other pests. In any fruit harvesting and packaging program, there is considerable inspection and culling of fruit. Inspection and culling occurs at harvest, during transit and during packaging. The level of scrutiny is greatest for export programs so that exporters can avoid loss of markets or additional costs; in general, shipments of infested or inferior fruit are either rejected at the port of entry or subjected to additional treatments to mitigate pest risk. In Mexico's program, only the best fruit are harvested for the export market, and of those that transit to the packing house, only about 50% are actually selected for the export market. This baseline provided our estimates for program A. Again, we estimated conservatively. We estimated that the probability that seed weevils would not be detected, despite close scrutiny including large amounts of fruit cutting (*i.e.*, dissection of fruit with the express purpose of looking for internal pests) to be as high as 20%. We estimated that the addition of inspections conducted by U.S. officials in the packing houses in Mexico would decrease these probabilities by one order of magnitude.

P3: Pest survives shipment

Some of these pests have been intercepted when individuals try to smuggle avocado fruit into the U.S. We therefore estimated the probability that these pests could survive transit to be high (70-90%), regardless of whether the fruit are refrigerated during transit.

P4: Pest not detected at port of entry inspection

Port-of-entry inspectors are trained specifically to detect internal pests. However, not all fruit in a shipment can be dissected. Our estimates for these pests not being detected at the port-of-entry inspection were very conservative ranging from 25% to 90%.

P5: Fruit transported to area with suitable hosts and climate

Under program alternative A, avocado fruit could be shipped to any State within the U.S. Because we estimated that the largest markets in the U.S. for avocado fruit are in California and Florida we estimated the probability that avocado fruit imported into the U.S. from Mexico would be transported to area with suitable hosts and climate to range from 25-75% (*i.e.*, as little as 25% but as many as 75% of the imported avocado fruit would go to areas with suitable habitat). If fruit are only allowed into the northeastern U.S., the only way they could be transported to suitable habitats would be due to smuggling or intentional diversion of shipments. Under program alternative B, it would be relatively easy to detect smuggling or intentional diversion of shipments because Hass avocado fruit are not otherwise generally available in those areas during the winter months.

P6: Infested fruit in suitable habitat leads to outbreak

These estimates are based on the known outbreak frequency of *Anastrepha* fruit flies in the U.S. and the known interception rate of these fruit flies at U.S. borders. Our conservative (*i.e.*, high) estimate for the maximum number of *Anastrepha* outbreaks is that one *Anastrepha* outbreak occurs for every 1,000 *Anastrepha*-infested lots entering the U.S. This probability was considered to be half for the other pests. These probabilities do not depend on which program is considered.

3. Calculate estimated probabilities of pest outbreaks.

We calculated estimated probabilities of pest outbreaks for each of the four pests/pest categories, for each of the two program alternatives (i.e., we ran eight separate Monte Carlo simulations). We used Monte Carlo sampling techniques account for the uncertainty of estimated probabilities. For example, because we were uncertain about the probability of grove infestation, we examined all pertinent information and agreed on the lowest and highest reasonable estimates. By choosing a minimum and maximum value with no value within the range considered to be more likely than any other, we specified a uniform distribution of probabilities. When the Monte Carlo simulations are run (*i.e.*, when the calculations are made to estimate the probability of pest outbreaks), any probability value

within the specified limits may be used in the calculations. To increase our confidence that we modeled a sufficient range of reasonable probability combinations, we calculated each of the final probabilities 1,000 separate times by running the Monte Carlo simulations with 1,000 iterations. Thus, for each of the two program alternatives, for each pest/pest category, we obtained 1,000 probabilities of a pest outbreak. The Monte Carlo simulations provided quantitative estimates of the frequency of outbreaks for the four pests/pest categories under the two scenarios and constitute a quantitative risk assessment. We used the personal computer program *@Risk* for Excel (Palisade Corp., Newfield, NY, USA) to run our simulations.

Table 5. Input data for Monte Carlo simulation: Fruit flies - *Anastrepha fraterculus, A. ludens, A. serpentina, A. striata*				
Frequency (F_n) / Probability (P_n)		Distribution	Minimum	Maximum
Program Alternative: — A — No Specific Mitigation Program				
A - F_1:	boxes of fruit imported per year	uniform	2,000,000	20,000,000
A - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.0001	0.001
A - P_2:	pest not detected during harvest or packing	uniform	0.001	0.1
A - P_3:	pest survives shipment	uniform	0.7	0.9
A - P_4:	pest not detected during port of entry inspection	uniform	0.7	0.9
A - P_5:	fruit transported to habitat suitable for pest	uniform	0.25	0.75
A - P_6:	infested fruit suitable habitat leads to outbreak	uniform	0.0001	0.001
Program Alternative: — B — Systems Approach for risk mitigation				
B - F_1:	boxes of fruit imported per year	uniform	1,000,000	2,000,000
B - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.0000001	0.00001
B - P_2:	pest not detected during harvest or packing	uniform	0.0001	0.01
B - P_3:	pest survives shipment	uniform	0.7	0.9
B - P_4:	pest not detected during port of entry inspection	uniform	0.7	0.9
B - P_5:	fruit transported to habitat suitable for pest	uniform	0.005	0.05
B - P_6:	infested fruit in suitable habitat leads to outbreak	uniform	0.0001	0.001

Table 6. Input data for Monte Carlo simulation: Seed weevils - *Conotrachelus aguacatae, C. perseae, Heilipus lauri*				
Frequency (F_n) / Probability (P_n)		**Distribution**	**Minimum**	**Maximum**
Program Alternative: — A — No Specific Mitigation Program				
A - F_1:	boxes of fruit imported per year	uniform	2,000,000	20,000,000
A - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.0001	0.001
A - P_2:	pest not detected during harvest or packing	uniform	0.002	0.2
A - P_3:	pest survives shipment	uniform	0.7	0.9
A - P_4:	pest not detected during port of entry inspection	uniform	0.5	0.8
A - P_5:	fruit transported to habitat suitable for pest	uniform	0.25	0.[illegible]5
A - P_6:	infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005
Program Alternative: — B — Systems Approach for risk mitigation				
B - F_1:	boxes of fruit imported per year	uniform	1,000,000	2,000,000
B - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.00001	0.0001
B - P_2:	pest not detected during harvest or packing	uniform	0.0002	0.02
B - P_3:	pest survives shipment	uniform	0.7	0.9
B - P_4:	pest not detected during port of entry inspection	uniform	0.5	0.8
B - P_5:	fruit transported to habitat suitable for pest	uniform	0.005	0.05
B - P_6:	infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005

Table 7. Input data for Monte Carlo simulation: Stem weevil - *Copturus aguacatae*			
Frequency (F_n) / Probability (P_n)	Distribution	Minimum	Maximum
Program Alternative: — A — No Specific Mitigation Program			
A - F_1: boxes of fruit imported per year	uniform	2,000,000	20,000,000
A - P_1: pest infests fruit: pre- or post-harvest	uniform	0.01	0.1
A - P_2: pest not detected during harvest or packing	uniform	0.002	0.2
A - P_3: pest survives shipment	uniform	0.7	0.9
A - P_4: pest not detected during port of entry inspection	uniform	0.7	0.9
A - P_5: fruit transported to habitat suitable for pest	uniform	0.25	0.75
A - P_6: infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005
Program Alternative: — B — Systems Approach for risk mitigation			
B - F_1: boxes of fruit imported per year	uniform	1,000,000	2,000,000
B - P_1: pest infests fruit: pre- or post-harvest	uniform	0.001	0.01
B - P_2: pest not detected during harvest or packing	uniform	0.0002	0.02
B - P_3: pest survives shipment	uniform	0.7	0.9
B - P_4: pest not detected during port of entry inspection	uniform	0.7	0.9
B - P_5: fruit transported to habitat suitable for pest	uniform	0.005	0.05
B - P_6: infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005

Table 8. Input data for Monte Carlo simulation: Seed moth - *Stenoma catenifer*				
Frequency (F_n) / Probability (P_n)		Distribution	Minimum	Maximum
Program Alternative: — A — No Specific Mitigation Program				
A - F_1:	boxes of fruit imported per year	uniform	2,000,000	20,000,000
A - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.0001	0.001
A - P_2:	pest not detected during harvest or packing	uniform	0.001	0.1
A - P_3:	pest survives shipment	uniform	0.7	0.9
A - P_4:	pest not detected during port of entry inspection	uniform	0.25	0.5
A - P_5:	fruit transported to habitat suitable for pest	uniform	0.25	0.75
A - P_6:	infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005
Program Alternative: — B — Systems Approach for risk mitigation				
B - F_1:	boxes of fruit imported per year	uniform	1,000,000	2,000,000
B - P_1:	pest infests fruit: pre- or post-harvest	uniform	0.00001	0.0001
B - P_2:	pest not detected during harvest or packing	uniform	0.0001	0.01
B - P_3:	pest survives shipment	uniform	0.7	0.9
B - P_4:	pest not detected during port of entry inspection	uniform	0.25	0.5
B - P_5:	fruit transported to habitat suitable for pest	uniform	0.005	0.05
B - P_6:	infested fruit in suitable habitat leads to outbreak	uniform	0.00005	0.0005

c. Results: Estimated Probability/Frequency of Pest Outbreaks

Results of the Monte Carlo simulations are shown in Tables 9 and 10. Because the probability of pest outbreak was calculated 1,000 times for each Monte Carlo simulation (*i.e.*, 1,000 times for each pest/pest category, for each of the two program alternatives), we present the results by specifying details of the output distribution. The center columns of Tables 9 and 10 present details of the resulting output distributions (*i.e.*, the mode and mean of the probability distribution, and the minimum and maximum values) in terms of the frequency of pest outbreaks per year. In the far right column, we present our best estimate for the number of years between pest outbreaks (calculated as the inverse of the mode of the outbreak frequency). By "best estimate" we mean the estimate for which we have the greatest confidence. Both tables present the same results, but Table 9 is organized by pest so that program alternatives can be compared for given pests, and Table 10 is organized by program alternative so that the program alternatives can be compared more easily.

Table 9. Pest Outbreak Frequency: Mexican Avocado Pests, By Pest

Pest	Program Alter-native	Outbreak Frequency (per year)				Number of years between outbreaks [2]
		Mode [1]	Mean [1]	Minimum [1]	Maximum [1]	
Fruit flies	A	0.0139	0.0518	0.000202	0.547	72
	B	8.64×10^{-8}	3.57×10^{-7}	2.02×10^{-10}	3.45×10^{-6}	> million
Seed weevil	A	0.0105	0.0419	0.000151	0.415	95
	B	6.66×10^{-7}	3.13×10^{-6}	1.18×10^{-8}	2.62×10^{-5}	> million
Stem weevil	A	1.389	5.183	0.0202	54.756	0.7
	B	8.77×10^{-5}	0.000387	1.35×10^{-6}	0.00345	11,402
Seed moth	A	0.00282	0.0120	3.99×10^{-5}	0.111	355
	B	1.87×10^{-7}	8.98×10^{-7}	3.46×10^{-9}	7.34×10^{-6}	> million

[1] See text for description of these terms.
[2] Calculated as inverse of mode.

Table 10. Pest Outbreak Frequency: Mexican Avocado Pests, By Program						
Program Alternative	**Pest**	**Outbreaks Frequency (per year)**				**Number of years between outbreaks** [2]
		Mode [1]	**Mean** [1]	**Minimum** [1]	**Maximum** [1]	
A **No specific mitigation program**	Fruit flies	0.0139	0.0518	0.000202	0.547	72
	Seed Weevil	0.0105	0.0419	0.000151	0.415	95
	Stem Weevil	1.389	5.183	0.0202	54.756	0.7
	Seed Moth	0.00282	0.0120	3.99×10^{-5}	0.111	355
B **Systems approach for risk mitigation**	Fruit flies	8.64×10^{-8}	3.57×10^{-7}	2.02×10^{-10}	3.45×10^{-6}	> million
	Seed Weevil	6.66×10^{-7}	3.13×10^{-6}	1.18×10^{-8}	2.62×10^{-5}	> million
	Stem Weevil	8.77×10^{-5}	0.000387	1.35×10^{-6}	0.00345	11,402
	Seed Moth	1.87×10^{-7}	8.98×10^{-7}	3.46×10^{-9}	7.34×10^{-6}	> million

[1] See text for description of these terms.
[2] Calculated as inverse of mode.

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